

## **ABSTRACT**

### **Cindy F. Linskey: Assessment of Carbon Monoxide Levels in Four Vehicle Remarketing Facilities (Under the direction of W. Jon Wallace)**

At vehicle remarketing facilities, also known as auto auctions, unacceptable carbon monoxide levels are possible due to vehicles running in an enclosed building. This study assesses and compares the levels of carbon monoxide at four vehicle remarketing facilities. The facilities were separated by vehicle volume and designated as large, medium, small A, and small B facility.

The carbon monoxide levels at the large dealer auction were lower than the levels at the medium and small facilities. The levels at the large auction were within health and safety guidelines while there was at least one breach of guidelines at the three public facilities. Several factors could have contributed to the variation such as differences in ventilation characteristics, the nature of the auction, and vehicle characteristics.

The conclusion was that the levels of carbon monoxide at certain vehicle auctions were not within certain occupational and public health standards. Levels such as were recorded during sampling could pose health problems for sensitive population within the general population.

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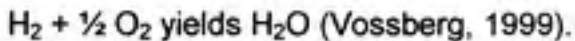
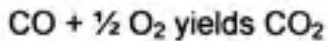
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## INTRODUCTION

Carbon monoxide (CO) is a colorless, odorless gas produced by the incomplete combustion of carbon-containing material such as fossil fuels. It is estimated that carbon monoxide related exposure sends approximately 40,000 people to the hospital every year resulting in an average of 3700 deaths. Carbon monoxide exposure is mostly dictated by microenvironments related to personal behavior, occupation, interior appliances, mode of transportation, and cigarette smoke. Considering unintentional poisonings, motor vehicle exhaust accounts for 57% of exposures (Penney, 2000). Even with this figure, rates of death from motor vehicle induced carbon monoxide poisoning has been on the decline for the past 20 years due to advances in automobile emission control technology spurred by air pollution legislation.

Regarding motor vehicles, the main sources of reduction in emissions have resulted from the introduction of onboard computers, oxygen and pressure sensors, and the three-way catalytic converter on vehicles. Onboard computers orchestrate and monitor the entire emission system. Oxygen sensors regulate the air/fuel ratio reducing the possibility of a fuel rich mixture and thus a high CO emission rate (Vossberg, 1999). Catalytic converters oxidize carbon monoxide to less toxic carbon dioxide (CO<sub>2</sub>) using metallic catalysts thus reducing carbon monoxide emissions even more. Catalytic converters, introduced in 1975, initially dropped CO emission rates to 6 g/min. By 1989 new cars were idling at 0.22 g/min. Contemporary catalytic converters result in greater than 99% elimination

of carbon monoxide in vehicle emissions (Vossberg, 1999). The equations for the conversion of carbon monoxide within the catalytic converter are as follows:



Due to the predominance of gasoline engines within the U.S. car fleet and fundamental differences between gasoline and diesel engines, discussion of diesel emissions will be omitted. Emission factors have been calculated under numerous driving conditions, and even well tuned gasoline engines produce measurable carbon monoxide. When an engine has been off for more than 30-60 minutes the engine cools considerably. The subsequent cold-start results in an intentional fuel rich start in order to improve ignition and idle (Marr, 1998). At the same time, the catalyst in the catalytic converter is not sufficiently warm to convert exhaust gases such as carbon monoxide to less harmful gases. In the time it takes the catalyst to sufficiently warm up, very high carbon monoxide emissions can result. In addition, as a vehicle ages, natural wear causes the vehicle's exhaust system to emit higher concentrations of carbon monoxide in the exhaust gas (Marr, 1998). In areas where emission-related legislation is not enforced, the public often fails to maintain or removes key emission components due to financial reasons or due to the misconception that emission controls limit performance of the vehicle.



Exposure to significant levels of carbon monoxide in enclosed spaces is of particular danger to employees and the general public in certain situations. This may result from the vehicle being serviced in a garage, indoor sporting events, or other use of internal combustion vehicles in enclosed spaces. Ventilation is sometimes thought to be adequate when in fact concentrations of carbon monoxide are building up to dangerous levels. Thus any vehicle running in an enclosed area may result in an unacceptable level of carbon monoxide concentrations. At a vehicle remarketing facility, vehicles travel through enclosed buildings to be viewed and bid on by spectators.

Vehicle remarketing facilities are found in every state in the United States. There are 179 auction facilities in the seven southeast states of Florida, Georgia, Alabama, South Carolina, North Carolina, and Virginia (Used, 2003). There are typically two types of auction facilities, dealer auctions and public auctions. An estimated 50-60 percent of a dealer's used car inventory comes from remarketing facilities (Martin, 2003). Whereas dealer auctions are very restrictive regarding attendance, public auctions are usually free and open for anyone to attend.

Vehicles are brought from a holding yard and driven through a building in which spectators stand and examine the cars as they come through. The vehicle is stopped for a brief time, but remains running through its turn at auction. The next vehicle follows close behind and is driven into the building for auction in a

repetitive process that continues until the last vehicle is auctioned. Small community auctions may only have one lane whereas larger auction facilities may contain 10 or more lanes through which cars are brought. The building has retractable bay doors that are open for the vehicle to travel in and out of the building, but is otherwise enclosed. Adequate ventilation is a factor that is often difficult to determine in dealing with hazardous gases such as carbon monoxide. The indoor aspect of a vehicle auction has potential to trap emissions such as carbon monoxide inside and reach unacceptable levels.

### **Health and Regulations**

Carbon monoxide enters the bloodstream through the lungs and attaches to hemoglobin, the body's oxygen carrier, forming carboxyhemoglobin (COHb). Toxicity results primarily from lack of oxygen at the cellular level caused by the impedance of oxygen delivery and utilization. Carbon monoxide reversibly binds to hemoglobin with an affinity approximately 240 times higher than oxygen, and causes an increased binding of oxygen molecules at the three other binding sites decreasing the availability of oxygen to already hypoxic tissues. Carbon monoxide intoxication has the most prominent effect on organs with higher metabolic demands, thus higher oxygen demand, such as the brain and heart. CO is eliminated via the lungs and, in an adult, has a half-life of 3-4 hours at room air temperature and pressure. The carboxyhemoglobin level measured in the blood sometimes does not correlate with the individual symptoms reported (Shochat, 2001).

The amount of carbon monoxide absorbed by a person depends on ventilation rate, length of exposure and concentration of carbon monoxide and oxygen in the enclosed space (Vossberg, 1999). Chronic exposures to carbon monoxide also occur and are studied less. Acute exposure displays characteristic symptoms that are more easily recognized than chronic exposure. Long exposure to small quantities over an extended period of time manifests differently in each individual affected. It is often mistaken for atypical pneumonia, chronic fatigue syndrome, psychiatric condition, or viral illness. This prolongs diagnosis and treatment for the person chronically exposed (Penney, 2000). Environmental factors that exacerbate CO poisoning include high CO concentrations in the air, prolonged duration of exposure, exposure at altitude (above 1500 meters), exposure during exercise or strenuous work, simultaneous exposure to other toxic agents, or individual susceptibility (Penney, 2002).

Pathological conditions that may increase individual susceptibility are heart disease, chronic lung disease such as emphysema or chronic obstructive pulmonary disease (COPD), anemia, fever, or diabetes (NIOSH, 1989). Possible effects on the cardiovascular system includes increased coronary blood flow, increased heart rate, and low blood pressure (Penney, 2002). In people with cardiovascular disease, hypoxic stress, caused by excessive carbon monoxide in the blood, further impairs cardiac function. When the body's compensatory mechanisms are overpowered or limited due to pre-existing disease, tissue injury is the result. Exposure to carbon monoxide that results in 3-5% COHb in the

blood impairs cardiovascular function in people with cardiovascular disease. OSHA notes that cardiovascular disease and pulmonary impairment, detected and undetected, are widespread in the general population in the United States, and that workers constitute a large part of this general population (NIOSH, 1989).

Susceptible populations may also be at a greater risk of injury due to carbon monoxide exposure. Senior citizens, young children, and fetuses in utero make up a considerable portion of the susceptible population. Senior citizens likely have pre-existing medical conditions that make them more sensitive to CO exposure. In young children, compensatory physiological mechanisms seen in adults may not work adequately due to immaturity. In unborn fetuses, maternal carbon monoxide intoxication is thought to cause congenital defects, prematurity, and low birth weight. The reasons for fetal sensitivity to low levels of carbon monoxide are: a more rapid metabolic rate, high oxygen demand, rapid cell division, naturally low oxygen environment, high affinity of fetal hemoglobin for carbon monoxide, compensatory mechanisms not available, CNS development occurs throughout pregnancy (Penney, 2002).

The National Institute for Occupational Safety and Health (NIOSH) recommended exposure limits that are based on concerns relating to occupational disease, primarily cardiovascular disease. The Recommended Exposure Limit (REL) is 35 ppm for an eight-hour time weighted average with a 200 ppm ceiling (NIOSH, 1994). The American Conference of Governmental

Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) is based on a shift in carboxyhemoglobin concentration in the blood by 3.5%. The TLV for carbon monoxide is 25 ppm for an eight-hour time weighted average (ACGIH, 2002). The Occupational Safety and Health Administration's (OSHA) Permissible Exposure Limit (PEL) is based on the feasibility of controlling exposures in various industries where agents may be present. OSHA's PEL is 50 ppm for an eight-hour time weighted average. OSHA also has an Instantaneous Exposure Limit of 1,200 ppm (OSHA, 1999). The Environmental Protection Agency (EPA) has established their National Ambient Air Quality Standards (NAAQS) at 9 ppm for an eight-hour time weighted average and 35 ppm for a one-hour time weighted average. This is set to protect the most sensitive members of the population and is based on a blood carboxyhemoglobin concentration shift of less than 2.1% (EPA, 1985). Typically if the public is exposed, NAAQS are used to determine acceptable limits. (Morley, 1998). The World Health Organization (WHO) has established criteria for carbon monoxide exposures that can be used for mixed public audiences. The WHO suggest an eight-hour time weighted average of 10 ppm and a one-hour time weighted average of 25 ppm (Levesque, 2000). See Table 1.1 for a summary of standards and regulations.

**Table 1.1**  
**Summary of Standards and Regulations**

Organization	Standard	Limits	Description
NIOSH	REL Ceiling	35 ppm 200 ppm	8 hr. TWA 15 min. TWA
ACGIH	TLV	25 ppm	8 hr. TWA
OSHA	PEL IEL	50 ppm 1,200 ppm	8 hr. TWA Instantaneous
EPA	NAAQS	9 ppm 35 ppm	8 hr. TWA 1 hr. TWA
WHO	N/A N/A	10 ppm 25 ppm	8 hr. TWA 1 hr. TWA

### **Purpose**

This study is an investigation into the potential for exposure to carbon monoxide at vehicle remarketing facilities. In order to protect the anonymity of the businesses involved, the vehicle remarketing facilities have been given generic names based on auction volume. The experimental framework used in this study is the taking of ambient air samples at four such facilities. The previous limits established to control exposures to carbon monoxide, and the use of vehicles indoors suggest the hypothesis that concentrations of carbon monoxide during vehicle remarketing sales may result in unacceptable levels for employees and the public in attendance. Thus, investigation into the levels of carbon monoxide

that result from vehicle auctions may provide useful insight into a potentially hazardous situation for all individuals involved.



## LITERATURE REVIEW

### Vehicle Studies

According to Diaz et. al., there are four contributing factors in high emitters: lean fuel/air ratio, rich fuel/air ratio, partial combustion, and deteriorating catalyst performance. In the study, the level of carbon monoxide was measured in flue gases before and after the catalytic converter. Vehicles with lean/rich mixtures accounted for the majority, and another thirty-eight percent of vehicles had faulty catalysts. The study suggested that a small loss of control in air/fuel ratio or heavy use of the vehicle could turn a vehicle into a high emitter (Diaz, 2001). The study also concluded that the performance of the catalytic converters tested was constant to approximately 40,000 miles with a steady increase in emissions to 65,000 miles. Thus, catalyst efficiency did not last for the life of the vehicle and showed deterioration after 40,000 miles. The conclusion is contrary to the automakers claims that the catalytic converter will last the life of the car (Diaz, 2001). Also concerning catalyst efficiency, Marr et al. noted that if a cold vehicle was started and left to idle, the catalyst may never reach a high enough temperature to operate effectively (Marr, 1998). Lower ambient temperatures increase time for heated catalyst to reach effective operating temperature (Singer, 1999). A study by Bishop et al finds that malfunctioning oxygen sensors also caused great variability in emissions. The sensors may work spontaneously, then malfunction causing high carbon monoxide emissions (Bishop, 1996).



In a low idle test conducted in California's Smog Check Program, survey data showed that, on average, idle emissions increase as vehicle ages, but high emitters are found in all model years, not just oldest vehicles. Also, when newer technology malfunctions the resulting emissions of carbon monoxide are often higher than a well maintained older vehicle (Lawson, 1993). Different states of maintenance among vehicles of model year far outweigh average effect of age (Beaton, 1995). A study done in Mexico City examining the long-term efficiency of catalytic converters shows that model year of vehicle is not a good characteristic to determine whether or not catalytic converter has diminished capabilities. Vehicles could become super-emitters in 5000 miles, 45,000 miles, or 100,000 miles (Harrington, 1994).

Although inspection and maintenance programs have made a difference in polluted areas, there are loopholes that exist which allow high emitters to keep operating the malfunctioning vehicle. According to Bishop et. al., inspection and maintenance programs designed to identify and remediate polluters are often ineffective. Vehicles are escaping the repair component and returning to road as non-compliant vehicles. Bishop calls this the "clean for a day" phenomenon. The study showed that many vehicles tested in the study would not pass the California emissions test, but did pass when tested at an official inspection station (Bishop, 1996).

### **Situational studies**

A series of road tunnel studies were completed in Taiwan, Canada, and United States. U.S. tunnels sampled for carbon monoxide were the Fort McHenry tunnel (under Baltimore harbor) and the Tuscarora Mountain tunnel (Pennsylvania turnpike). A comparison was made of roadway grade differences and the release of emissions determined due to uphill and downhill portions of roadway (Pierson, 1996). Under high throttle conditions, a power enrichment occurs. In a closed loop three-way catalyst system, power enrichment means that the onboard computer controls the command to a rich air/fuel mixture. The result is an open loop operation with no feedback from the oxygen sensor to control the air/fuel mixture. Very high CO can result with up to 2500 times normal CO being emitted. Tests showed concentrations lower than NAAQS levels. The study concluded that due to power enrichment, emission rates for uphill grades were double the amount emitted for downhill or level road grades (Pierson, 1996).

### **Indoor Studies**

A potentially dangerous situation was brought to the attention of the National Institute for Occupational Safety and Health (NIOSH) regarding The Crown US Hot Rod Monster Truck and Motocross Show in Cincinnati, OH in November 1998. The situation was unique in that the monster trucks had no emission reduction systems in place and did not represent conventional vehicles being operated indoors. Personal and area monitoring with a one minute sampling interval showed that while the eight-hour time weighted average was not

exceeded, ceiling limits and one-hour time weighted averages were exceeded on many occasions. The show was sampled for two days and the variability from the two days was noted. On the more severe day, ten downdraft fans were not used and the air handling units were recycling fifty percent of the air. According to NIOSH, ventilation is the key to controlling exposures during indoor vehicle events (Morley, 1998).

In another study done, a monster truck competition was held in an indoor ice skating rink in Canada in 1996. Personnel were set up with gas monitors. Ceiling levels as well as OSHA's Instantaneous Exposure Limit (IEL) value of 1200 ppm was breached several times. The conclusion was that no motor vehicle event was to be held indoors at the rink during the winter because the natural ventilation used is not adequate during this time (Levesque, 2000).

A sampling event at an indoor tractor pull in Manitoba, Canada in 1988 produced unacceptable levels of carbon monoxide. Levels were 262 and 435 ppm by the end of the two separate events. The conclusion was that remediation was needed before any more events were to take place (CDC, 1990).

Another area of concern relating to carbon monoxide exposure levels is auto repair shops. A NIOSH Health Hazard evaluation originally was conducted to test for isocyanates during spray painting at Spence's Carstar, an auto body repair shop in Denver, Colorado. NIOSH investigators also measured CO while they

were there sampling at the location. Their findings were that carbon monoxide concentrations were elevated due to cars being brought in and out of and moved around in the building. Although the ceiling limit was not exceeded, the 8-hour time weighted average equaled the ACGIH TLV of 25 ppm. The concentrations were high enough that remediation was determined to be needed in order to control exposures (NIOSH, 1996). According to NIOSH, the best possible solution was to increase building dilution ventilation. A similar investigation at Matrix Auto Body revealed an 8-hour time weighted average of 54 ppm, which is more than double the ACGIH TLV of 25 ppm. Similar suggestions were made regarding ventilation (NIOSH, 1996).

A study in a parking garage during March 1997 focused on the differences in hot emissions in morning and cold-start in afternoon. The catalytic converter was characterized as hot in the morning due to the warm up during the commute to work. The cold-start in the afternoon was due to the cooling of the catalytic converter in the nonmoving vehicle during the day. The results indicated that levels of carbon monoxide were three times higher in afternoon than morning. The catalytic converter which converts carbon monoxide to carbon dioxide is not adequately heated by engine exhaust gases in the cold-start situation and results in higher carbon monoxide buildup in the parking garage (Singer, 1999).

### **General Health Studies**

OSHA has characterized the effects of various levels of carbon monoxide in the air as related to carboxyhemoglobin levels in Table 2.1.

**Table 2.1**  
**Effects of Various Levels of Carbon Monoxide**

Atmospheric CO (ppm)	COHb%	Effects
70	10	Shortness of breath following exercise
120	20	Occasional headache with throbbing
220	30	Headache, fatigue, dizziness, impaired vision
350-520	40-50	Headache, collapse, fainting
800-1200	60-70	Unconsciousness, convulsions, respiratory failure
1950	80	Rapidly fatal

(OSHA, 1993)

In a study by Allred et. al., male subjects with history of coronary artery disease who had exercise induced angina and changes in their electrocardiogram were exposed to carbon monoxide to reach specified levels of COHb in the blood. A significant dose-response was observed for the individual differences in the time of angina and EKG abnormalities onset when comparing pre- versus post-exposure exercise tests. The conclusion was that low doses of carbon monoxide produce significant effects on cardiac function during exertion in subjects with coronary artery disease (Allred, 1991).

Also, in another cardiac study, pre-existing data sets in seven U.S. cities were analyzed to examine association between hospital admissions for congestive heart failure and air pollutants. Ambient CO levels and daily variations in levels were positively associated with hospital admissions for cardiac heart failure in the pollutant models used (Morris, 1995).

In a study concerning asthma by Sheppard et. al., daily hospital non-elderly admission data and daily ambient criteria pollutants for asthma were compared and modeled. Particulate matter and carbon monoxide observed to be jointly associated with asthma admissions (Sheppard, 1999).

In a fetotoxicity study in Seoul, Korea, the relationship between maternal carbon monoxide exposure and the contribution to low birth weight was evaluated. Authors used air pollution data and medical records to model exposure and results. Their conclusion was that the risks for having low birth weight babies tended to increase with carbon monoxide exposures between 2-5 months of pregnancy (Lee, 2003).

### **Worker-Specific Studies**

An epidemiological study in India looked at respiratory symptoms and lung function in garage workers and taxi drivers. Results were a high prevalence of respiratory symptoms associated with exposure to motor vehicle exhaust in garage workers (Bener, 1998).

Another epidemiological study (survey) in India on traffic police, bus drivers, and auto shop workers studied the relationship of the level of hemoglobin in the blood to occupational exposure to motor vehicle exhaust. Potula et al measured levels of hemoglobin in study participants. Results concluded that increased exposure to motor vehicle exhaust as determined by job category was significantly associated with a lower hemoglobin level. Employment duration as an auto shop worker or bus driver was significantly correlated with lower hemoglobin levels. The study concluded that motor vehicle exhaust has a hemosuppressive effect with chronic exposure (Potula, 1996).

Due to the correlation of operating vehicles in enclosed spaces and elevated levels of carbon monoxide in the air, vehicle remarketing facilities could represent a potential health hazard to workers and/or the general public. For this reason, comprehensive studies are necessary to determine the level of carbon monoxide present and whether the level is within regulatory limits.



## METHODOLOGY

This study consisted of a series of sampling events at four separate vehicle remarketing facilities to test for the levels of carbon monoxide in the air. At one facility, three repetitive sampling sessions were done. At the other three facilities, a single sampling event was accomplished. In order to protect the anonymity of the businesses involved, the vehicle remarketing facilities have been given generic names based on auction volume. The delineation was made as follows:

Large – over 1000 vehicles auctioned per auction event

Medium – 500 to 1000 vehicles auctioned per auction event

Small – under 500 vehicles auctioned per auction event

Sampling methods were based on NIOSH method 6604 (Included in Appendix A).

### Materials

Air sampling for carbon monoxide was done with a Bacharach Snifit Carbon Monoxide Analyzer, Model 50. The meter has an electrochemical sensor specific to carbon monoxide and a digital readout with a resolution of 1 ppm. The meter was factory calibrated before sampling began and is equipped with a manual zero mechanism. The operating temperature range is 32 to 104 deg. F.

Timing for the sampling was accomplished with a basic stopwatch set to countdown and alarm every minute. Data recording was done with a clipboard, paper, and a pen.



## **Large Auction**

### Background

This facility was a dealers only auction in a medium-sized city in central North Carolina. This auction facility has the capacity for 16 lanes of vehicle auction space. On the days of sampling the auction began at 9:00 am and lasted until approximately 2:00 pm with no intermissions. Between 5000 and 6000 cars passed through the auction facility during each day of sampling. An estimated 1500 people were in attendance. Sampling was conducted March 5, March 12, and March 19 of 2003.

The building was ventilated by a main air handling unit which connected to three exhaust vents and two return ducts in each lane. While a lane was running, the entrance and exit bay doors remained open. Due to lanes opening and closing at staggered times, sampling was done in the middle lane of operation. See Figure 1 for a diagram of the large auction facility.

## **Medium Auction**

### Background

This event was a public auto auction located in the suburbs of a large city in Georgia. This auction facility has the capacity for four lanes of vehicle auction space. On the days of sampling the auction began at 6:30 pm and lasted until approximately 10:00 pm with no intermissions. Approximately 600 cars passed through the auction facility during the evening of sampling. An estimated 200 people were in attendance. Ventilation consisted of one exhaust fan in the ceiling

in lanes one and two. Sampling was done in lanes two and three. See Figure 2 for a diagram of the medium auction facility.

### **Small Auction A**

#### Background

This facility was a public auction in a medium-sized city in central North Carolina. This auction facility has the capacity for 3 lanes of vehicle auction space. On the days of sampling the auction began at 7:00 pm and lasted until approximately 10:00 pm with no intermissions. Approximately 450 cars passed through the auction facility during the evening of sampling. An estimated 150 people were in attendance. Ventilation consisted of an exhaust fan in the ceiling of lane two. Sampling was done in lane two. See Figure 3 for a diagram of the small A auction facility.

### **Small Auction B**

#### Background

This facility was a public auction in a small city in eastern North Carolina. This auction facility has the capacity for two lanes of vehicle auction space. On the days of sampling the auction began at 7:30 pm and lasted until approximately 10:00 pm with no intermissions. Approximately 150 cars passed through the auction facility during the evening of sampling. An estimated 40 people were in attendance. Ventilation consisted of an exhaust fan mounted in the wall beside the exit bay door. The auction involved only one lane that evening. See Figure 4 for a diagram of the small B auction facility.

## **Methods**

Prior to and following the auctions, the temperature, humidity and winds were determined from the national weather service. After arriving at the auction facility, the meter was turned on in fresh air and brought into the building. A background reading was taken and recorded. During sampling the meter was held approximately four and a half feet from the ground, which was within the breathing zone of the person sampling. Sampling was begun when the cars' ignitions were started in anticipation for the auction to begin. Sampling was done by recording the digital readout from the carbon monoxide meter every minute, as indicated by a stopwatch and alarm. Sampling continued every minute until the last car rolled out. Ventilation layout was noted and any irregularities in activity were noted.

## **Data analysis**

The data collected was analyzed and all charts were generated in Microsoft Excel. The analysis consisted mainly of averaging to determine various time-weighted averages and to determine vehicle characteristics.

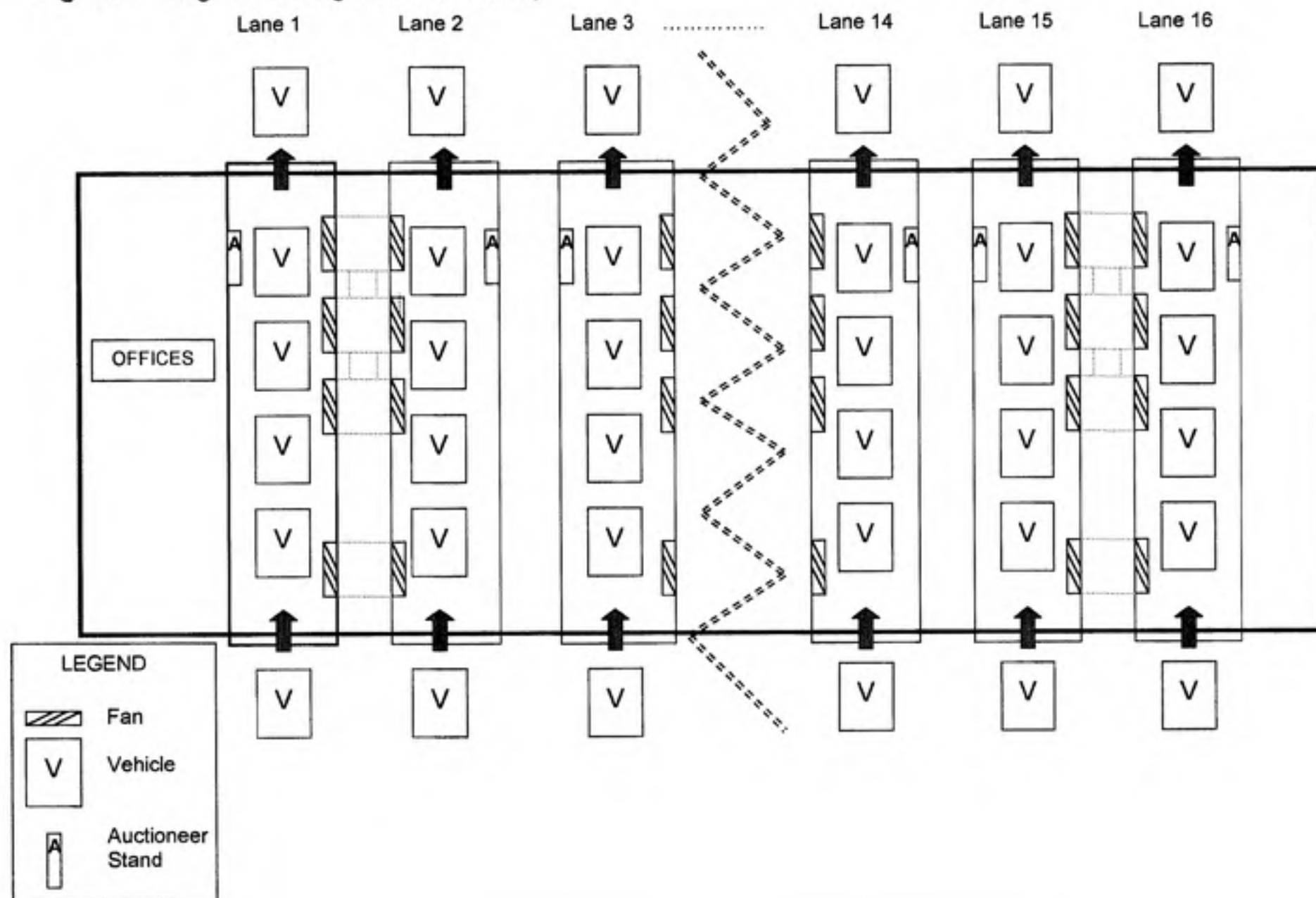
Calculations:

8-hour TWA:  $\text{Sum of sampled concentrations (entire period)} / 480 \text{ min.}$

1-hour TWA:  $\text{Sum of sampled concentrations (one hour increments)} / 60 \text{ min.}$

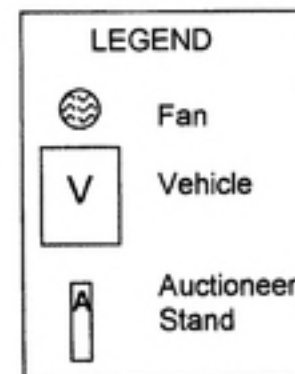
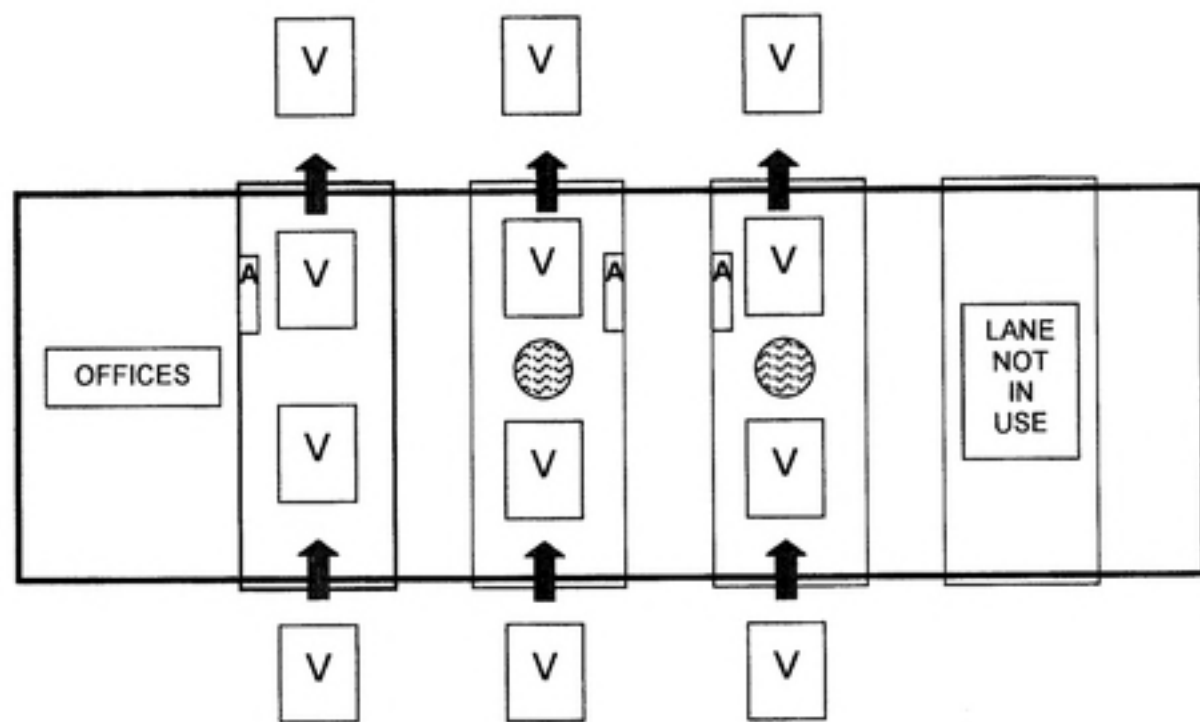
STEL:  $\text{Sum of sampled concentrations (15 minute increments)} / 15 \text{ min.}$

**Figure 1** Diagram of Large Auction Facility



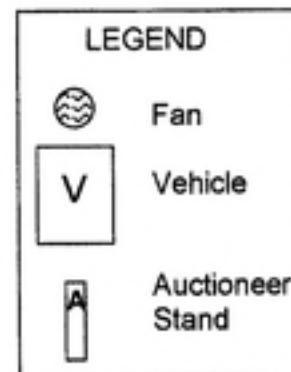
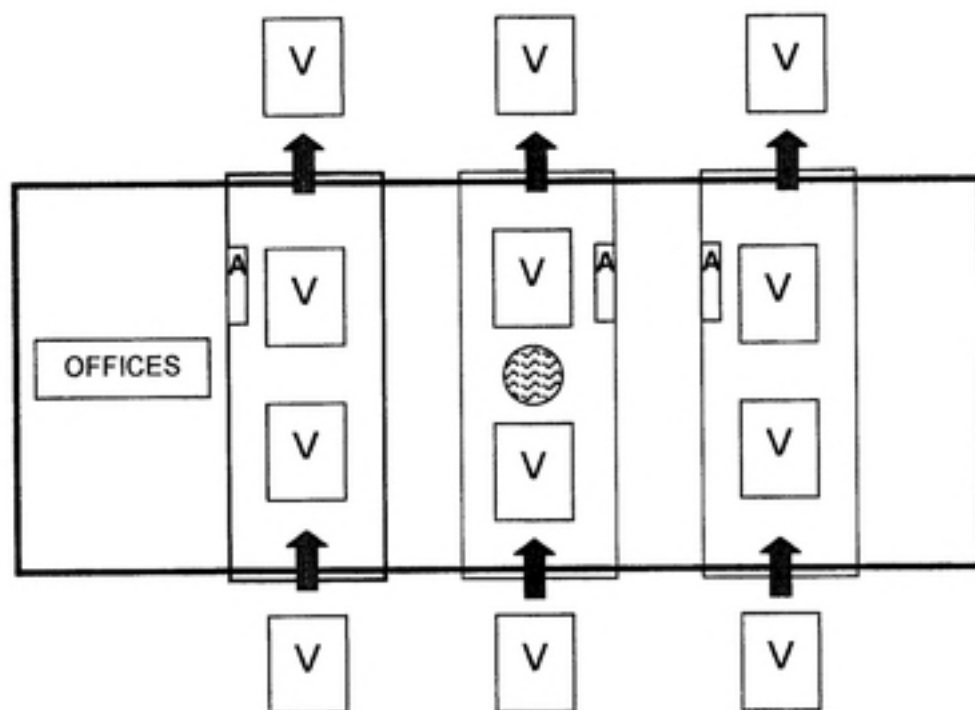
**Figure 2**

Diagram of Medium Auction Facility



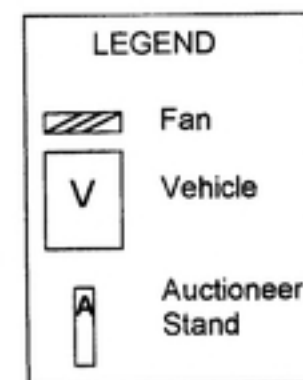
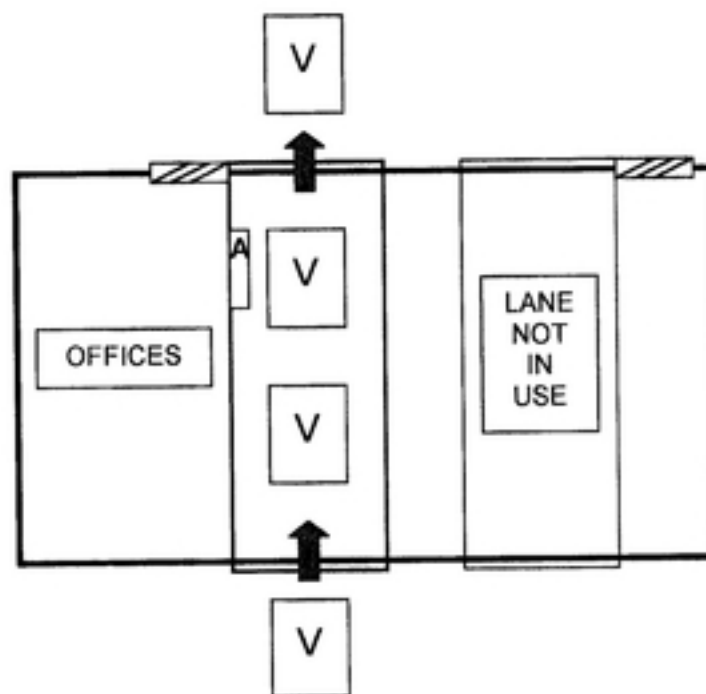
**Figure 3**

Diagram of Small A Auction Facility



**Figure 4**

Diagram of Small B Auction Facility



## RESULTS

Carbon monoxide sampling was completed at four separate facilities with seven sampling events. Charts containing the data spread are included in Appendix B. Auction date and time as well as weather data are summarized in Table 4.1. Auction characteristics such as number in attendance, number of workers, total number of cars auctioned, average model year of the cars and the mileage were determined. The results are summarized in Table 4.2.

For comparison among the auction facilities, Table 4.3 lists eight-hour time weighted averages and peak concentration at during each sampling event. Sampling times actually ranged from 2-5 hours with unsampled time assumed to be 0 ppm for 8-hour TWA. The large auction was sampled three times and the other three facilities were sampled once.

In addition, one-hour time weighted averages, consecutive time periods, are represented in Table 4.4. In order to represent short-term exposures, the data was divided into fifteen minute segments and averaged. The consecutive short-term exposure levels (STELs) are represented in Table 4.5. The highest sixty-minute and 15-minute time segments were averaged and are represented in Table 4.6. All results are shown in parts per million (ppm).



**Table 4.1**  
**Sampling Data: Time and Weather Conditions**

	Large	Large	Large	Medium	Small A	Small B
Date Sampled	3/5/03	3/12/03	3/19/03	3/21/03	3/27/03	3/31/03
Time Auction Began	9:00 AM	9:00 AM	9:00 AM	6:30 PM	7:00 PM	7:30 PM
Temperature (Beginning)	50°	41°	52°	60°	56°	48°
Temperature (End)	61°	54°	46°	58°	53°	47°
Humidity (%)	53	63	95	54	73	45
Winds (mph)	5 - 10	calm	5 - 10	calm	calm	5 - 10
Precipitation	none	none	rain	none	none	none

**Table 4.2**  
**Auction Characteristics**

	Large 3/5/03	Large 3/12/03	Large 3/19/03	Medium	Small A	Small B
Estimated Number of Employees Exposed	80	80	80	8	8	4
Attendance (Public)	1500	1500	1500	200	150	40
# Vehicles	5000-6000	5000-6000	5000-6000	600	450	150
Average model year	2000	2000	2000	1995	1994	1993
Average mileage (grouped)	0-49,999	0-49,999	0-49,999	Over 100,000	Over 100,000	Over 100,000

**Table 4.3**  
**Eight-Hour Time Weighted Average and Peak Concentration**

	Large 3/5/03	Large 3/12/03	Large 3/19/03	Medium	Small A	Small B
8-hr. TWA* (ppm)	2	2	1	14	17	5
Peak Concentration (ppm)	33	78	30	1583	593	280

Results are shown in ppm

\*Less than 8 hours sampled, unsampled time assumed 0 ppm conc.

**Table 4.4**  
**One-Hour TWA (Consecutive Intervals)**

Time Frame (Min.)	Large 3/5/03	Large 3/12/03	Large 3/19/03	Medium	Small A	Small B
0-59	3	5	2	21	32	24
60-119	2	2	2	65	87	12
120-179	4	5	3	23	17	--
180-239	4	2	1	--	--	--
240-299	2	2	1	--	--	--

Results are shown in ppm

**Table 4.5**  
**Short Term Exposure Levels (15 Minute Consecutive Intervals)**

Time Frame (Min.)	Large 3/5/03	Large 3/12/03	Large 3/19/03	Medium	Small A	Small B
0-14	2	2	1	5	65	34
15-29	3	9	1	3	15	32
30-44	4	3	1	44	32	13
45-59	3	5	4	31	17	16
60-74	2	1	1	23	38	23
75-89	2	1	1	180	109	19
90-104	1	2	2	40	111	7
105-119	2	2	2	16	91	--
120-134	2	8	2	22	21	--
135-149	4	3	2	21	19	--
150-164	6	7	5	37	25	--
165-179	3	2	3	12	--	--
180-194	5	2	1	--	--	--
195-209	4	1	1	--	--	--
210-224	4	4	2	--	--	--
225-239	2	2	1	--	--	--
240-254	2	2	2	--	--	--
255-269	3	1	1	--	--	--
270-284	2	2	1	--	--	--
285-299	2	1	1	--	--	--
300-314	1	1	1	--	--	--

Results are shown as ppm

**Table 4.6**  
**Highest One-Hour and Fifteen Minute Time Weighted Averages**

	Large 3/5/03	Large 3/12/03	Large 3/19/03	Medium	Small A	Small B
Highest 1-hour TWA	5	5	3	77	87	27
Highest 15-Min. Ceiling (STEL)	8	9	6	202	172	56

Results are shown in ppm

Vehicles were observed emitting visible smoke and vapors. This often correlated with a higher reading on the carbon monoxide meter. Correlating events are shown in Table 4.7.

**Table 4.7**  
**Peak Readings With Correlating Events**

Facility	Reading	Event
Large	30	Smoking 1996 V10 Superduty Truck
	53	1998 Dodge 4x4
	78	2002 RAM 2500
		Cumming Turbo Diesel
	59	1998 Dodge Work Van
Medium	1583	1991 Chevrolet Blazer—Smoking Profusely
Small A	300	1988 Ford Mustang
	556	Wrecker pulling car through auction
	593	1986 Honda Accord
		Smoking
	396	Wrecker pulling car through auction
Small B	230	Wrecker pulling car through auction
	280	1988 Ford Truck
		Smoking
	94	1995 Toyota Camry
	95	1993 Jeep Cherokee

Some facilities were not within health and safety limits set by occupational and public health organizations. These breaches are represented in Table 4.8.

**Table 4.8**  
**Lack of Compliance to Established Standards**

	NIOSH		ACGIH	OSHA		EPA		WHO	
	REL	Ceiling	TLV	PEL	IEL	8-Hour TWA	1-Hour TWA	8- Hour TWA	1-Hour TWA
Large 3/5/03									
Large 3/12/03									
Large 3/19/03									
Medium		Ø			Ø	Ø	Ø	Ø	Ø
Small A						Ø	Ø	Ø	Ø
Small B									Ø

Ø denotes non-compliance with standard

Human exposure may vary within a facility based on proximity to the polluting source and barriers to the pollution. Sampling of office space adjacent to the auction lanes and separated by a door or series of door is represented in

Table 4.9.

**Table 4.9**  
**Sampling in Adjacent Offices**

	Large 3/5/03	Large 3/12/03	Large 3/19/03	Medium	Small A	Small B
Within 6 ft of Door	2	1	2	14	10	5
20 ft from Door	1	1	1	8	9	3

Results are shown in ppm

Sampling was one instantaneous reading in offices

The nature of the auction seemed to make a difference in carbon monoxide levels. Readings at the large dealer auction were considerably lower than all of the public auctions attended.



## DISCUSSION

The purpose of this study was to determine the level of carbon monoxide that was present in vehicle remarketing facilities during an auction and to compare the results with one another as well as to established health and safety limits. Due to fundamental differences in the events of the auction and facility difference, the large auction facility will be discussed separately.

### **Large Auction Facility**

The large auction facility was sampled on three separate occasions during the study. The auction was open to vehicle dealers only, had a high volume of vehicles pass through, and was conducted in a professional business-like manner. The results showed that the level of carbon monoxide during the auction on all three days were acceptable when comparing the levels to all criteria set by health and safety organizations. The eight-hour, one-hour, and fifteen-minute time weighted averages were all under 10 ppm. The most obvious factor contributing to the low carbon monoxide readings was the ventilation. There were three exhaust vents and one return vent per lane. The difference in air flow created negative pressure which drew a continuous breeze through each auction bay. In addition, the ventilation was running and the bay doors were open before the vehicles' engines were started ensuring that a preliminary buildup did not occur. Another difference with the large auction facility was the age of the building. The building was considerably newer than the other three auction facilities.

The only area of concern at the large auction facility was under special circumstances. During a random sampling event in which two cars were started with the ventilation on and all bay doors closed, the carbon monoxide readings reached unacceptable levels. The result was a fifteen-minute TWA of 92 ppm, which is still under the NIOSH ceiling of 200 ppm. One of the vehicles was a hot rod in which the exhaust system had been modified. The other was a high performance sports car with contemporary emission controls. The restriction of the ventilation due to the closed doors and carbon monoxide output of the modified vehicle most likely caused the higher level of carbon monoxide.

#### **Medium/Small Auction Facilities**

The medium and both small auction facilities were different in fundamental ways. The overall volume of the buildings was much less than the large facility. The volume of cars passing through the auction was also lower. Though there was less theoretical potential for carbon monoxide due to the ten-fold decrease in the number of vehicles, the outcome was a different one.

At the medium facility, the levels of carbon monoxide were within the eight-hour TWA limits set by the occupational health organizations NIOSH, ACGIH, and OSHA at 14 ppm for the calculated eight-hour TWA. However, the 14 ppm TWA is above the recommended eight-hour TWA of the EPA and the WHO which is 9 ppm and 10 ppm respectively. The NIOSH ceiling level is 200 ppm, and one fifteen-minute time weighted average at the medium facility was 180 ppm. The EPA one-hour TWA, and the WHO one-hour TWA of 35 ppm and 25 ppm

respectively were both breached by the levels of carbon monoxide present with a calculated one-hour TWA of 65 ppm at the medium facility. In addition, OSHA's Instantaneous Exposure Limit (IEL) of 1200 ppm was surpassed by more than 300 ppm on one occasion with a reading of 1586 ppm. Ventilation seemed to be the limiting factor regarding carbon monoxide removal. There were single exhaust fans in the ceiling over lanes one and two of the four lane auction facility. Signs posted in each lane warned: Danger, Carbon Monoxide May Be Present. The use of signs at this facility only may be due to local regulations or permitting.

At the small A facility, the levels were also within all specified eight-hour TWA limits relating to occupational health, but were over the EPA and WHO suggested TWA with a calculated eight-hour TWA of 17 ppm. The EPA one-hour TWA and the WHO one-hour TWA were also surpassed for two hours with readings of 87 ppm and 32 ppm for the first and second hour respectively. With a single fan over lane two of the three-lane facility, ventilation was probably not adequate to remove the carbon monoxide generated in the building.

At the small B facility, all eight-hour TWA were met with a calculated eight-hour TWA of 5 ppm. Calculated ceiling and one-hour TWA were all within limits set by the health and safety organizations. Though levels here were higher than the large facility, and ventilation capacity was similar to the medium and small A facilities, placement of the fans may have played a part in a lower overall concentration of carbon monoxide in the building. The fans were placed not in

the ceiling, but in the wall by the exit bay door. The placement may have facilitated air movement within the bay, which lowered the concentration of carbon monoxide.

In the majority of instances at all four facilities, when peaks in carbon monoxide concentration occurred, visible smoke was apparent from one or more vehicles inside or entering the building. In some cases, the smoke visibly distressed members of the public. The typical response by people would be to cover their noses and mouth with their shirt or handkerchief, fan the air with their hands, or leave the building. Several people were seen using inhalers or eye drops. The use of such aids may or may not have a correlation with the irritation of the exhaust smoke.

A major difference between the large dealer only facility and the other three facilities is that at the public vehicle auctions the average model year of vehicles was older, mileage was on average over 100,000 miles, and overall maintenance was poor. These three factors more than likely contributed to the higher readings at the three smaller facilities.

Another factor to consider in the sampling for carbon monoxide is the amount of second-hand smoke present from cigarette smoking. The zero time point represented the background created by any crowd activity such as smoking. There were 1-2 ppm background readings at the large facility before the auction

began. The reading may involve cigarette smoke, but more than likely represents the levels in the building created when the initial set of cars were driven in and the doors were closed again before the auction started. Small variations in meter readings could have occurred due to isolated incidents of cigarette smoke within close proximity of the meter.

### **Employee and Public Exposure**

The locations of employees and the public are very similar at each of the four facilities. The auctioneer stands behind a tall auctioneer stand and beside him is the client whose vehicles are currently for sale. Sitting at a lower desk is an auction clerk(s) who handles the paperwork for the auction. Standing on the auction floor is a spotter who helps the auctioneer keep up with who is bidding. The setup is the same for all of the auctions with the number of employees depending on how many lanes are running. At the large facility, there was at least one worker at each lane mopping the lane as each car came through the facility. The moisture from freshly washed cars dripped to the floor on occasion and the employee kept the floor clear of any accumulating water.

The auction lanes were marked with yellow paint with an approximate eight-foot buffer zone in between. The buffer area is where the majority of the public stood to view the vehicles and to bid in the auction. Some people stood outside at the entrance to the bay.

Based on the results from the sampling events, all of the auctions except for the large auction could cause adverse health effects in sensitive populations within

the total population. Sensitive populations include infants and small children, pregnant women, the elderly, people with chronic respiratory conditions such as asthma, and those with heart disease. During the days of sampling, senior citizens, pregnant women, infants, and children were seen in attendance at the public auctions. When looking after public welfare as a whole, sensitive populations must be protected also.

### **Study Limitations**

One limitation to the study regarding determination of employee exposures is the use of area sampling versus personal sampling. Individual exposures may differ greatly in certain circumstances and area sampling may not accurately capture an individual's exposure. To ensure with a 95% confidence level that an employee with an exposure in the top 20% of exposures is sampled, fourteen employees from the large auction facility, and six each from the medium auction facility, the small A auction facility, and the small B auction facility would need to be assessed with personal sampling devices.

A second limitation is the duration of sampling at each facility with regard to the 8-hour TWA calculation. The auctions did not last eight hours, and in calculations done to determine 8-hour TWA, unsampled time was designated to have zero ppm concentration of carbon monoxide. The employees and public, in reality, were not exposed for the whole eight hours, but the calculations were made to compare with health and safety standards and regulations.



Another limitation is in the number of samples taken at each facility. With only one sampling event at the medium, small A, and small B auction facilities, the typical exposure range may have been missed. The results may or may not represent the typical or average exposure on any given day. This project was designed to be a survey of each facility in order to determine if a possible hazard exists in which case more sampling may be done.

### **Possible Solutions**

Solving the problem of unacceptable levels inside vehicle remarketing facilities may take a multifaceted approach. Since many peaks in carbon monoxide concentration correlated with visible smoke coming from vehicles, perhaps an arrangement can be made to auction these cars outdoors or have them towed through the building to be auctioned. In the case of the auction at the Small A facility, the tow truck operated by the auction company was a factor in raising the carbon monoxide levels. Keeping facility-owned equipment maintained is an important factor in not contributing to the concentration of carbon monoxide.

More attention to ventilation of the buildings may also make a difference in the levels of carbon monoxide inside the building. An engineer would be needed to determine the appropriate ventilation design and strength for each individual vehicle remarketing facility.

Conducting in-house carbon monoxide monitoring on a routine basis may be helpful. Self-monitoring is not a solution in itself, but with an adequate self-monitoring program the facility management will be able to identify if a problem with carbon monoxide exists and to what extent. The sampling should include area sampling of the facility and personal sampling of employees during an auction. Monitoring could also include an industrial type carbon monoxide detector with a programmable alarm in order to alert when unacceptable levels have been reached.

An innovative change to dealer auctions is being implemented by the Auction Broadcasting Company (ABC) headquartered in Indianapolis, Indiana. The company calls its technological advance Auto Auction Theater Technology or A<sup>2</sup>T<sup>2</sup>. At the ABC facilities, dealers sit in a theater style room behind a solid glass wall through which the dealers observe the auction lanes and vehicles.

Television monitors in the room broadcast the action in each lane. Each seat is outfitted with computer terminals with which the dealers bid on and purchase the vehicles up for auction. From the Auction Broadcasting Company website, they claim the Auto Auction Theater Technology is "destined to change the face of the auto auction industry" (Auction, 2003).

For dealer auctions, the change is feasible because the cars are relatively new, all mechanical and cosmetic defects are noted, and the dealers are prepared to perform the necessary repairs at their dealership. The act of purchase of a



vehicle at a dealer auction is a bit distanced by lack of a personal stake in the vehicle. The A<sup>2</sup>T<sup>2</sup> technology would be more difficult to implement at a public auction due to the inherent nature of the auction. The people at a public auction are often there to purchase a vehicle for personal use, or to be placed on a small car lot. The bidders get close to the car to touch it, raise the hood, open and shut the doors, and listen to it run. The public gets involved in the auction, and this involvement would come to a halt behind a glass wall in a theater style auction facility. Even though the technology may be more difficult to implement in certain situations, the advancement would shield attendees from emissions from the vehicles or personal harm from moving vehicles.

Another possible alternative to indoor auctions is the increasingly popular online vehicle auctions. Some of the large dealer auctions also include weekly online auctions for clients. Other current online auctions include government auctions, eBay motors, and Yahoo.com auctions. The online auctions are ideal for eliminating carbon monoxide exposure, but, for the public, they have similar limitations to the theater-style auction facility.

Since major changes in vehicle auction protocol will take time, towing smoking vehicles through the auction, ensuring adequate ventilation, and self-monitoring are viable options that may be implemented by the auction facilities immediately.

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## **Appendix A**

NIOSH Method Number 6604

## CARBON MONOXIDE

6604

CO  
RTECS: FG3500000

MW: 28.00

CAS: 630-08-0

METHOD: 6604, Issue 1

EVALUATION: FULL

Issue 1: 15 May 1996

OSHA : 50 ppm  
NIOSH: 35 ppm; C 200 ppm  
ACGIH: 25 ppm  
(1 ppm = 1.14 mg/m<sup>3</sup>)

PROPERTIES: gas; BP -192 °C; MP -207 °C; vapor density (air=1) 0.967; flammable (explosive) limits in air 12.5 to 74.2%

SYNONYMS: monoxide; carbon oxide; carbonic oxide; flue gas

SAMPLING		MEASUREMENT	
<b>SAMPLER:</b>	PORTABLE DIRECT-READING CO MONITOR	<b>TECHNIQUE:</b>	ELECTROCHEMICAL SENSOR
<b>VOL-MIN:</b>	instrument dependent	<b>ANALYTE:</b>	carbon monoxide (CO)
<b>-MAX:</b>	none	<b>CALIBRATION:</b>	
<b>SHIPMENT:</b>	routine shipment of instrumentation	<b>- ZERO:</b>	CO-free air
<b>SAMPLE STABILITY:</b>	at least 7 days @ 25 °C [1] (aluminized air bags)	<b>-SPAN:</b>	standard cylinders of span gas in the desired range
<b>BLANKS:</b>	fresh air or compressed CO-free air from cylinder	<b>RANGE:</b>	0 to 200 ppm
<b>ACCURACY</b>		<b>ESTIMATED LOD:</b>	1 ppm
<b>RANGE STUDIED:</b>	0 to 200 ppm	<b>PRECISION <math>\hat{s}_x</math>:</b>	0.035 @ 20 ppm 0.012 @ 50 ppm 0.008 @ 100 ppm [2]
<b>BIAS:</b>	- 1.7% [2]		
<b>OVERALL PRECISION <math>\hat{s}_{\text{rel}}</math>:</b>	0.022 [2]		
<b>ACCURACY:</b>	± 6.0%		

**APPLICABILITY:** Portable, direct-reading carbon monoxide monitors are applicable to any work environment for personal or area monitoring.

**INTERFERENCES:** Several gaseous pollutants (e.g., NO<sub>2</sub>, SO<sub>2</sub>) may cause an interference at levels over 5 ppm. If these or other pollutants are known or suspected to be present, use a monitor with a chemical interference scrubber over the sensor. Unknown pollutants may require further experimentation to determine their effect on the sensor. As tested, SO<sub>2</sub> (5 ppm), CO<sub>2</sub> (5000 ppm), methylene chloride (500 ppm), diesel fuel (5 µL/L, about 0.3 ppm benzene), and gasoline vapor (1 µL/L, about 1 ppm benzene) had no impact on most monitor readings [2]. Some monitors are equipped with a chemical interference scrubber while others offer this as an option.

**OTHER METHODS:** Bag samples may be collected in aluminized bags (2-L or larger) and analyzed later by placing the calibration cap over the sensor and pumping the sample across the sensor at a nominal rate of 0.250 L/min with a personal sampling pump.

#### REAGENTS:

1. CO\*calibration gas, 20 to 50 ppm, compressed gas cylinder, appropriate pressure regulator, and other items as recommended by manufacturer for field check of monitor response.

\* See SPECIAL PRECAUTIONS

#### EQUIPMENT:

1. Carbon monoxide monitor; Envirocheck I single sensor CO Monitor (Quest Technologies); CO262 or STX70 (Industrial Scientific); MiniCO (MSA); or other electrochemical CO monitor with equivalent performance specifications.
2. Personal sampling pump, 0.250 L/min, with inlet and outlet, used for bag filling and sample analysis when off-site analysis is needed.
3. Air bags, aluminized, 2-L, or other appropriate sizes (optional).
4. Replacement batteries or battery recharger, as appropriate for monitor.

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**SPECIAL PRECAUTIONS:** Carbon monoxide is a highly flammable, dangerous fire and explosive risk, and is toxic by inhalation. Shipments of compressed calibration gas must comply with 49 CFR 1992 regulations.

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#### SAMPLING AND MEASUREMENT:

1. Zero monitor with CO-free air at the same temperature and relative humidity as the work environment, if possible.  
NOTE: Monitors are more sensitive to temperature variations than to humidity variations. Most monitors have temperature compensating circuitry.
2. For personal monitoring, locate the monitor as near the worker's breathing zone as possible.
3. For area monitoring, locate monitor in an area with good air circulation about 60 to 70 inches above the floor.  
NOTE: Make sure the sensor is not obstructed in either application.

#### CALIBRATION AND QUALITY CONTROL:

4. Calibrate with a standard calibration mixture of CO in air from a pressurized cylinder at the CO level recommended by the monitor manufacturer (Normally, 20 to 50 ppm CO). The monitor should be calibrated at the temperature and relative humidity as near as possible to that of the work environment in which it will be used.
5. Check the calibration daily and recalibrate whenever the monitor reading varies from the span gas by 5% or more, or as the manufacturer recommends.

#### CALCULATIONS:

6. Read concentration directly from the monitor display.

Some monitors (data logger models) will maintain a continuous record of the data as it is accumulated and will calculate the Average, TWA, Peak, etc. concentrations. These data may be read from the display at any time. Some monitors will also store this information for downloading to a computer or printer at the end of the monitoring period. Other monitors only display the current reading, requiring the operator to manually record the data. All monitor models are equipped with alarms that will warn the user (audibly, visually or both) whenever the concentration of CO exceeds the preset level of the alarm. Many are equipped with two-level alarms [3].

#### EVALUATION OF METHOD:

The performance of six direct-reading carbon monoxide monitors was evaluated over a period of 12 months



at CO concentrations up to 200 ppm and a range of ambient temperatures and relative humidities. Most of the tests were conducted at or near the PEL. For mean recovery studies, six different monitors were used and readings were taken approximately 1 h apart. Recovery at 20 ppm was 105% (n = 42); at 50 ppm, 99.6% (n = 36); and at 100 ppm, 99.9% (n = 30). Thus, the overall mean bias was calculated at - 1.7%. The precision (S<sub>y</sub>) at 20 ppm was 0.035 (35 readings from 5 monitors over a 7-h period). At 50 ppm, it was 0.012 (30 readings from 5 monitors over a 6-h period), and at 100 ppm, it was 0.008 (36 readings from 6 monitors over a 6-h period). Tests also were conducted to determine response time, zero and span drift, alarm decibel level, battery life, life of the sensors, as well as the effects of selected interferences (gases, vapors, and RF) and the effects of handling and transporting to remote sites.

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**METHOD WRITTEN BY:**

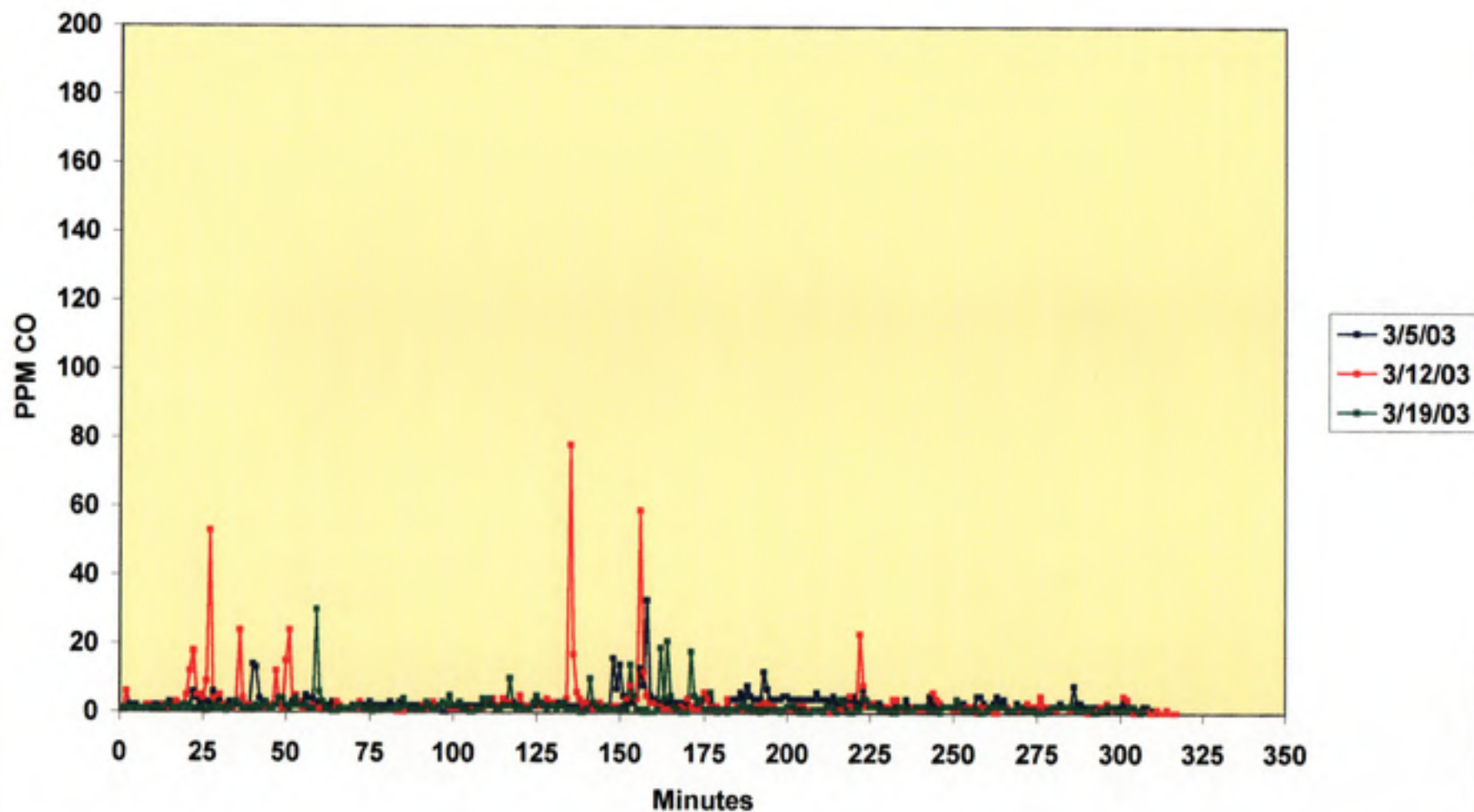
W. James Woodfin, NIOSH, DPSE, MRB



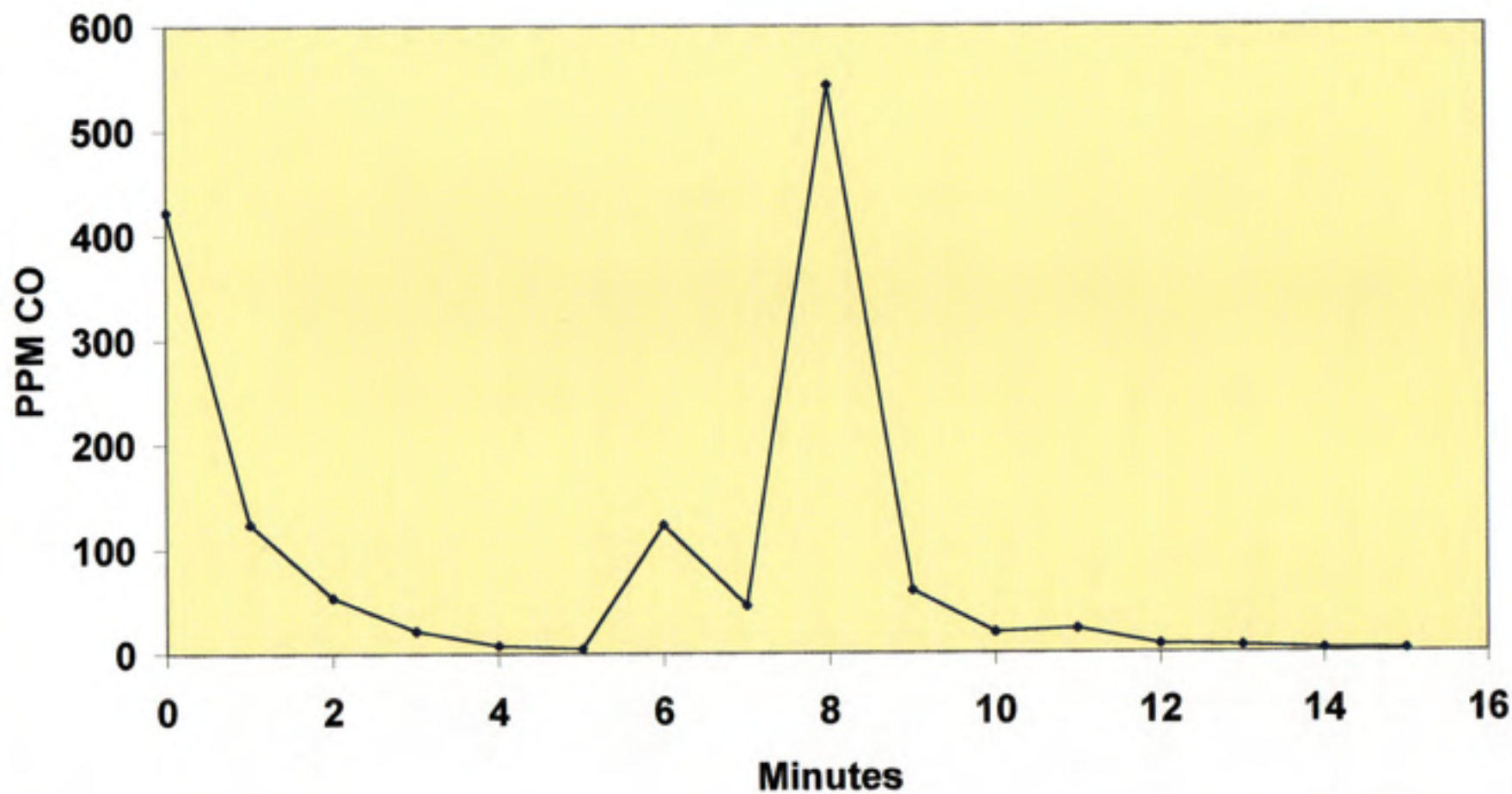
## **Appendix B**

Charts representing data taken at each of the four auction facilities

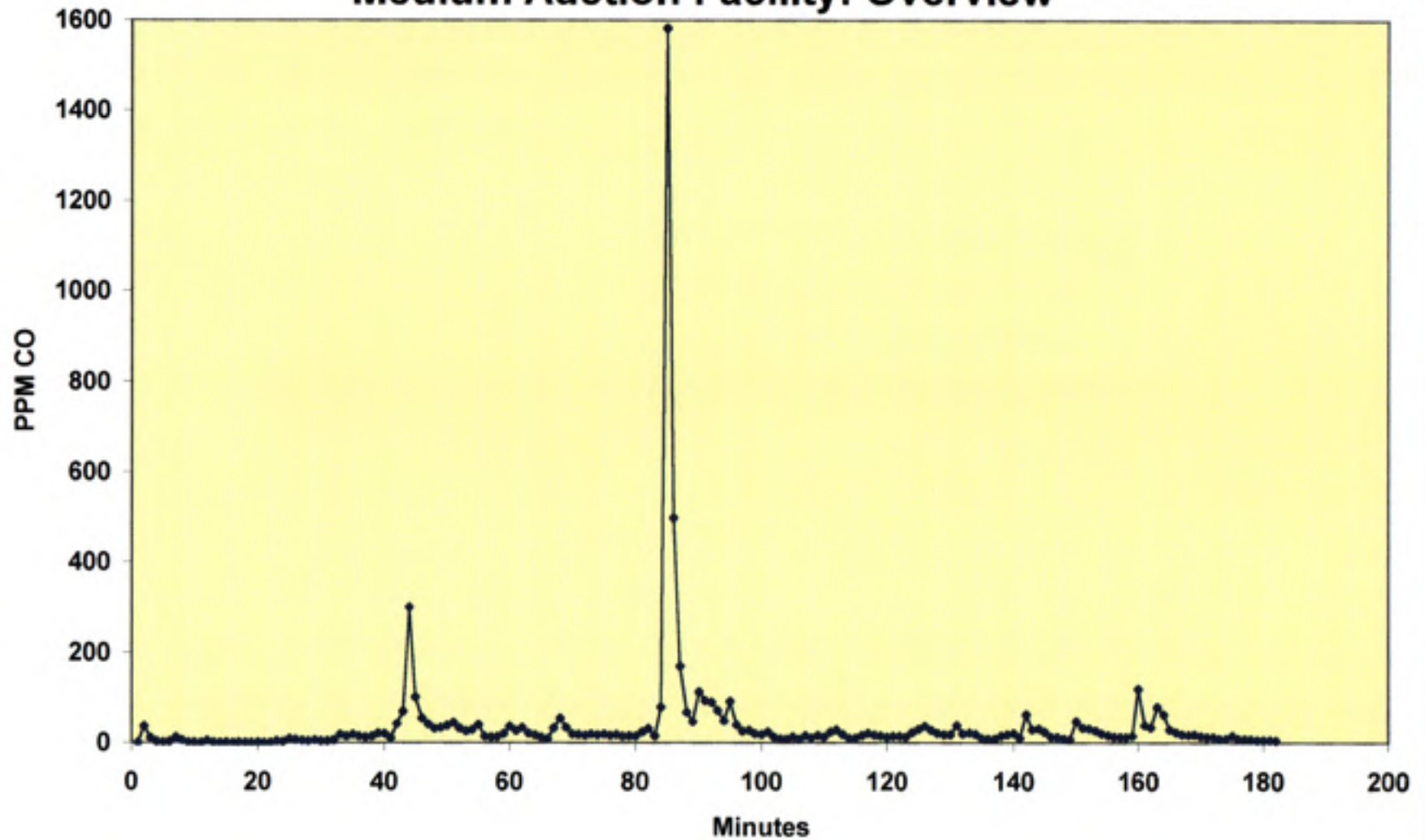
## Carbon Monoxide Levels Large Auction Facility



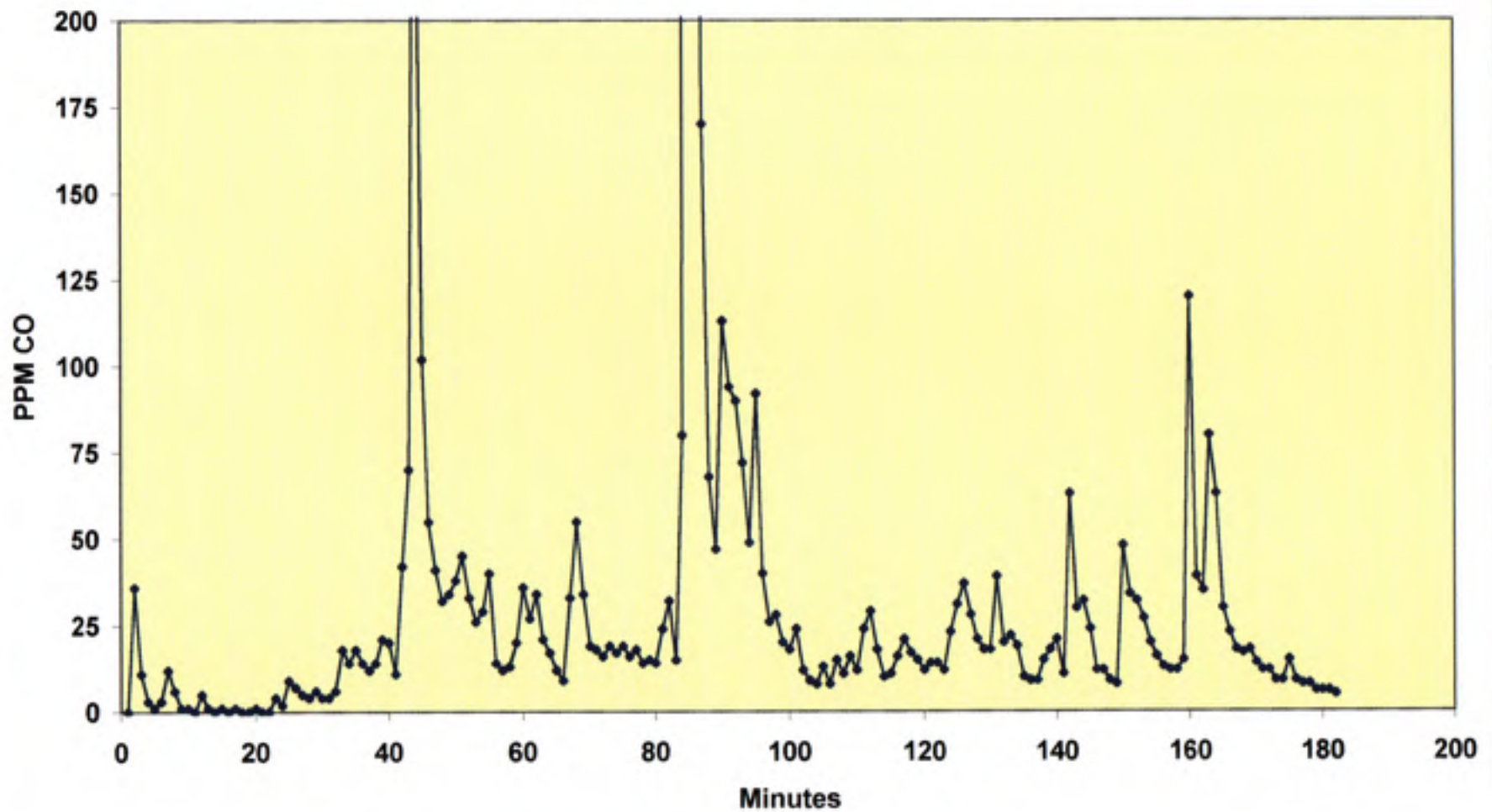
## Large Auction Facility Prowler/Hotrod Running, Doors Closed



## Carbon Monoxide Levels Medium Auction Facility: Overview

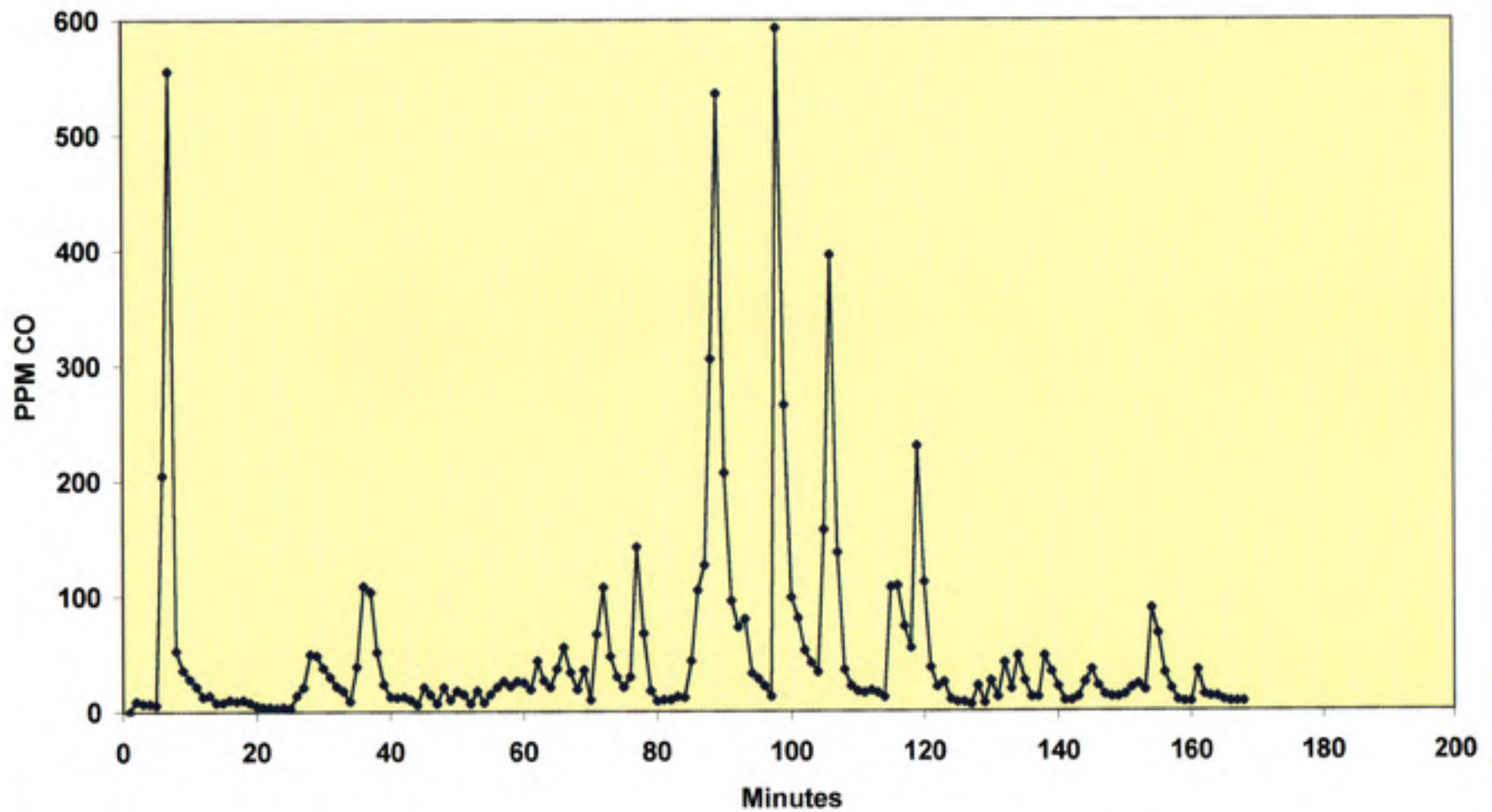


## Carbon Monoxide Levels Medium Auction Facility: Baseline Magnified



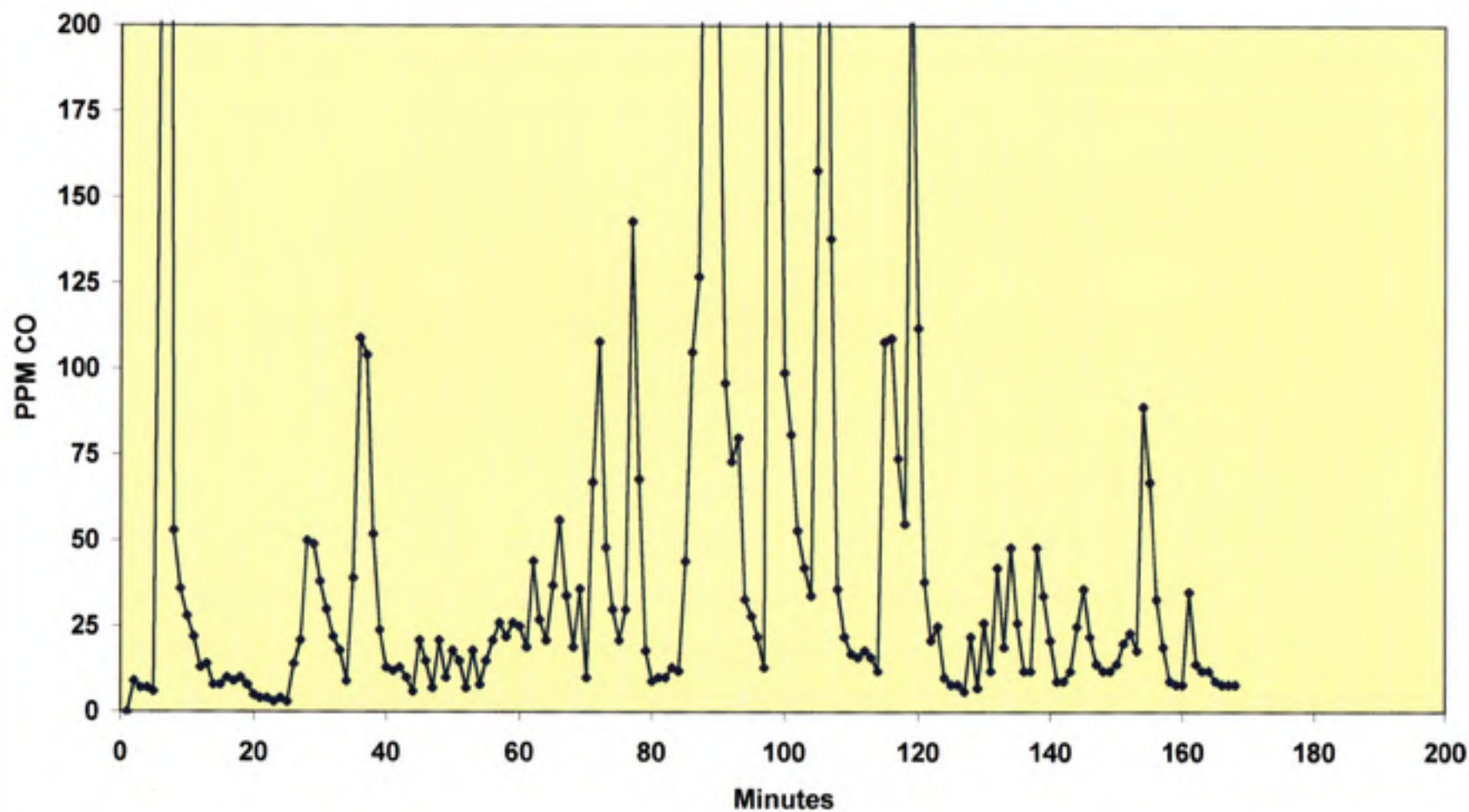


## Carbon Monoxide Levels Small A Auction Facility: Overview



# Carbon Monoxide Levels

## Small A Auction Facility: Baseline Magnified



## Carbon Monoxide Levels Small B Auction Facility

